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Ever since the publication of Fenton and Wright's work on ionically conducting polymers in 1973, the potential application of solid polymer electrolytes to solid state lithium batteries has led to an extensive investigation of their transport and electrochemical properties. Recent modeling studies on lithium/insertion cathode cells, including the design scale-up for both unipolar and bipolar configurations indicates the possibility of achieving high energy and power densities well in excess of the present advanced batteries. The recently reported work on polymer electrolyte batteries that operate from -20°C to $+100^\circ$C demonstrates the utility of this new class of lithium batteries.

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Ever since the publication of Fenton and Wright's work on ionically conducting polymers in 1973, the potential application of solid polymer electrolytes to solid state lithium batteries has led to an extensive investigation of their transport and electrochemical properties. Recent modeling studies on lithium/insertion cathode cells, including the design scale-up for both unipolar and bipolar configurations indicates the possibility of achieving high energy and power densities well in excess of the present advanced batteries. The recently reported work on polymer electrolyte batteries that operate from -20 °C to +100 °C demonstrates the utility of this new class of lithium batteries.

1. INTRODUCTION

Solid state rechargeable lithium polymer electrolyte batteries utilizing insertion cathodes represent one of the very active areas of lithium battery technology. A substantial amount of effort has been devoted to the characterization of polymer electrolytes as outlined in recent comprehensive review articles[1,2], but considerably less effort has been made on full cell studies. Although the successful cycling of small prototype cells have been reported[3-5], the development of larger area cells have been somewhat sluggish. However, the progress in the development of new polymer electrolytes with high ionic conductivities at ambient temperatures has expedited the research impetus of this all solid state concept. Hence, there is a strong need to model this type of battery system with respect to the energy and power capability.

2. MODELING STUDIES

The approach involved the macroscopic modeling of unipolar and bipolar prismatic configuration cells. The unit cell was based on the following configuration:

Ni || Li || Electrolyte || standard V_6O_{13} composite || Ni
(25 μm) (3 x cathode capacity) (0.2t_c) (t_c) (25 μm)
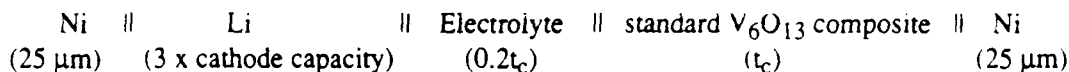
Metallized plastic (1000Å Ni layer) and aluminum current collectors were also considered. The theoretical specific energies and specific pulse powers were calculated for a wide range of cathode thicknesses (t_c) and cell areas. The details of the design concepts are discussed elsewhere[6].

3. RESULTS AND DISCUSSION

In order to increase the specific energy and specific power of a polymer electrolyte battery, one needs to employ a bipolar plate design. The use of a metallized plastic current collector is expected to decrease not only the weight and the cost, but also to increase the specific energy and power of the system considerably. There is however, a trade-off of one parameter over the other. For example, in order to obtain the maximum energy density, the power density must be sacrificed and vice versa.

Figure 1 shows a typical energy density variation with the number of bipolar units for the 100 μm thick cathode as a function of cell area for metallized plastic current collector. The optimum specific energy occurs for 5 bipolar units with cell area corresponding to 400 cm² and is about 470 Wh/kg. For thinner cathodes, these values are considerably lower. The values are also lower for the unit cell case and when employing metallic current collector.

Figure 2 shows a typical pulse power density variation with the number of bipolar units for 0% depth of discharge (fresh cell) and 1 μm thick cathode as a function of cell area for the metallized plastic current collector. Since the power is inversely proportional to the electrolyte film thickness which in turn is proportional to the cathode thickness, thinner cathode films yield high power density. Specific powers of almost 4 MW/kg are calculated for 20 bipolar units and 400 cm² cell areas. Lower power densities are calculated for the thicker cathodes and for the metallic current collector case.

Table 1 summarizes the optimum specific energies and powers calculated for unipolar and bipolar cells.

ACKNOWLEDGEMENT

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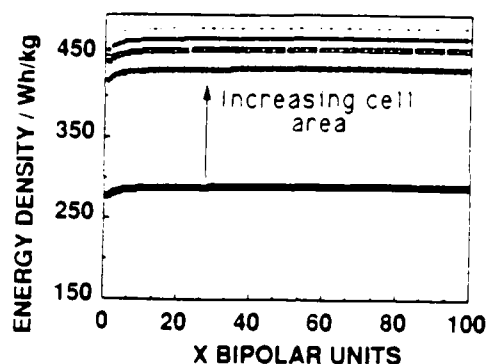

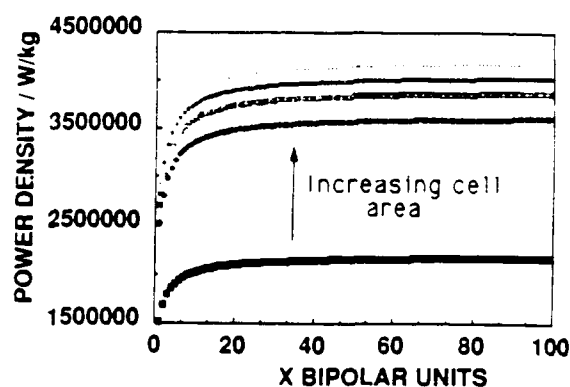Fig. 1 Variation of specific energy with number of bipolar units.

Fig. 2 Variation of specific power with number of bipolar units.

Table 1 Summary of Specific Energies and Powers for Unit and Bipolar Cells

ENERGY DENSITY IN Wh/kg FOR 20X20 cm CELL AND 100 μm CATHODE			
UNIT CELL		BIPOLAR CELL (40 UNITS)	
NICKEL	METALLIZED PLASTIC	Ni/Al	METALLIZED PLASTIC
240	460	450	470

POWER DENSITY IN MW/kg FOR 20X20 cm CELL, 0% DOD, 1 μm CATHODE			
UNIT CELL		BIPOLAR CELL (40 UNITS)	
NICKEL	METALLIZED PLASTIC	Ni/Al	METALLIZED PLASTIC
0.29	2.15	2.25	3.90